ON THE

DERANGEMENTS OF MOTION

FOLLOWING DIVISION OF THE

SEMICIRCULAR CANALS.

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PARIS.

(Translated by CLARENCE J. BLAKE, M. D., Boston.)

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ON THE DERANGEMENTS OF MOTION FOLLOWING DIVISION OF THE SEMICIRCULAR CANALS.

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One of the most curious facts educed by Flourens from his beautiful experiments on derangements of motion in animals is unquestionably that concerning the remarkable movements of the head, as well as of the rest of the body, in animals in whom the semicircular canals had been divided. Having been occupied for many years in the special study of the ear in health as well as in disease, I could not but take the greatest interest in these remarkable phenomena, and determined to undertake a further investigation of this interesting subject, the more so that I believed myself to have found some points of vantage which would lead to a nearer understanding of the mechanism of these symptoms. Instead, therefore, of simply repeating the experiments of Flourens as it had been heretofore done, it appeared possible, by a modification of the circumstances under which the division of the semicircular canals in animals was performed, to obtain further information concerning the conditions necessary to the occurrence of the phenomena. I hoped, for instance, to determine by experiment the question as to whether the movements

of the animal operated upon were really caused by pain, as Flourens believed, and whether, as a rule, consciousness was necessary to the occurrence of the derangements of motion.

The following pages will show how far my hopes were realized, and in what degree I have succeeded in contributing to an understanding of the nature of these mysterious facts. In regard to the curious movements which follow division of the semicircular canals, I would refer to the excellent description in Flourens's work (FLOURENS, *Recherches Expérimentales sur les Propriétés et les Fonctions du Système nerveux. Seconde édition*, page 454, iii.—460, VI.). The symptoms which I have observed in numberless experiments on division of the semicircular canals agree so fully with those portrayed in the work above cited, that I consider any further description of that which has been so often described as wholly superfluous, and will content myself with a concise statement of whatever may be worthy of mention that I have educed therefrom. In the first place, careful dissections of all the animals upon which I have operated have shown, contrary to the views of certain physiologists, that accidental injury of portions of the brain cannot be considered as constituting a cause of these remarkable phenomena.

Such injury accompanying division of the horizontal and small vertical canals is, moreover, entirely out of the question. This is not the case, however, according to my experience with the large (superior) vertical canal. The inner wall of this canal projects so far into the cranial cavity that it is impossible to effect complete

destruction of the canal without lesion of the cerebellum.

My experiments, furthermore, gave a result in opposition to the statement of Professor Czermak. According to his opinion, vomiting is a constant sequence of injury of the semicircular canals. On the contrary, in the large number of experiments which I instituted, this symptom was observed in but one case, following the operation upon a pigeon. As is shown, however, in the following record of the experiment in this case, an undue depth of the incision injured the cerebellum, and upon dissection an extravasation was found in this organ. The vomiting, therefore, was not the result of the injury to the canals, but of the inroad upon the cerebellum, and it appears very probable to me that a similar injury interfered with the experiments of Professor Czermak.

Experiment No. 1, *July* 11, 1869.—The left horizontal semicircular canal of a pigeon was divided on both sides of the vertical canal. The bird ran quietly about the room, and on being thrown down from the table immediately got upon its legs again. Fifteen minutes later, by means of a deep incision, the right horizontal semicircular canal was divided outwards from the vertical canal. Movements of the head from right to left immediately occurred, together with rotatory movements of the body in the same direction. The pigeon repeatedly fell suddenly to the ground; in a few moments there was a single attack of vomiting, and the movements continued.

July 14.—Continuance of the symptoms, but increased

in severity. The pigeon held the head firmly pressed upon the ground, in such position that the occiput rested upon the floor and the eyes were directed upwards. The movements consisted in rotation upon the long axis, and also upon the transverse axis (somerset), and, in addition, exceedingly complicated movements, the head being continually twisted from left to right (the right eye turning towards the left side); if the head was forced into its natural position, it immediately resumed the abnormal position so soon as it was released. (During sleep, and even sometimes while awake, the position of the head was normal!)

Death occurred on July 27th, at noon. The dissection, which was made on the 29th, showed extravasated blood to the right and left of the canals, the middle lobe of the cerepellum hyberæmic, the capillaries especially being filled with blood. Examined with the naked eye, this portion showed a peculiar greenish-yellow color. The osseous as well as the membranous canals were divided, and there was no trace of reunion. On the right side the incision had slightly entrenched upon the vestibule.

In proceeding to repeat the experiments of Flourens, I had in mind to investigate whether any conclusions could be arrived at concerning the nature of the cause of these disturbances. No one has as yet considered, for instance, the point as to whether the symptoms in question have their cause in an *irritation* or in a *paralysis* of the nerves, but it is primarily evident that this question must first be answered before a clear insight into the circumstances under considera-

tion can be obtained. I purposed, therefore, experimenting upon the effects of irritating these canals. The choice of irritants applicable to this purpose was very limited. The use of electricity presented the greatest difficulties, as it was impossible to fix the animal sufficiently for the purpose of observing the result of the irritation; similar objections precluded the use of mechanical means of irritation, as it is very difficult, during the observation of the disturbances of motion, to continue the application of the irritant. I concluded, therefore, to limit myself to the use of chemical irritants, and selected for this purpose common salt, in crystals or in saturated solution. The following experiment, selected from a number performed in the same manner, exhibits the result arrived at:

Experiment No. 2, *July* 17, 1869.—The small vertical canal on the right side in a pigeon was crushed with the forceps so that a portion of the membranous canal was visible. There immediately followed rotation of the head towards the right side, and falling towards the right on movement. A small piece of salt being placed upon the membranous canal, there was no change in the symptoms, but on application of a concentrated solution the bird showed an inclination to press the right side of the head against the wall, and the movements for some little time were more violent than before.

That we have here to deal with the phenomena of *irritation* appears to me unquestionably deducible from the fact that in all cases the application of a concentrated solution of salt is accompanied by an increase in vehe-

mence of the movements; in this connection the circumstance that the bird pressed the head forcibly against the wall, as if for the purpose of removing the cause of pain, is characteristic. These and analogous experiments appear to me, therefore, to prove that *the disturbances of motion consequent on division of the semicircular canals originate in an irritation of the membranous canals.*

We have further to inquire as to the nature of these disturbances of motion resulting from the irritation of peripheral structures. Have we to deal with simple reflex movements, or are the remarkable contortions of the animals operated upon the expression of a pain actually felt, and therefore consciously perceived? This question could be determined only by experiment, and there was but one means open for its solution, namely, the elimination of that organ upon the integrity of which the preservation of consciousness depends—the cerebrum. There were two methods of accomplishing this:

1. Simple extirpation of the cerebral hemispheres (easily performed in pigeons).

2. Anæsthetization of the animal experimented upon.

1. I cite a few experiments in which I endeavored to accomplish the object by the first of the measures above mentioned.

Experiment No. 3.—The cerebral hemispheres were wholly removed from a pigeon, the bird remaining quiet. Several of the semicircular canals on both sides were then divided; the characteristic movements immediately appeared and continued with great vehemence. Five

or six minutes later I removed nearly the entire upper half of the cerebellum. The movements continued with undiminished violence; possibly they were somewhat more complicated than before (?). The symptoms continued the same. On division of the spinal cord, the abnormal movements immediately ceased. (The reflex movements, however, continued.)

Experiment No. 4.—Several of the semicircular canals were divided on both sides in a pigeon. The characteristic symptoms immediately appeared. The cerebral hemispheres were then removed: the movements continued a few minutes and then subsided. The bird remained motionless, but so soon as it was touched or pushed the derangements of motion consequent on the division of the semicircular canals reappeared and continued for several minutes.

Experiment No. 5.—Several of the canals were divided on both sides in a pigeon, with the occurrence of considerable hemorrhage. The characteristic movements appeared as usual, and continued several hours after the removal of the cerebral hemispheres. On the following day the bird was quiet. The movements appeared immediately, however, when the pigeon was touched or pushed.

On examining these experiments more precisely, we find them to show first of all that the removal of the cerebral hemispheres exerts no influence on the occurrence of the derangements of motion, neither does their previous removal prevent the occurrence of the symptoms following division of the semicircular canals, nor are these symptoms resulting from division of the

canals thereby arrested. Removal of or injury to the cerebellum has also no influence on the occurrence of the movements, inasmuch as they can neither be made to cease nor can their occurrence be prevented by this means. Injury to the cerebellum, on the other hand, renders the movements still more complicated, as it adds to the symptoms consequent upon irritation of the semicircular canals those resulting from injury of the cerebellum.

In this connection Experiment No. 8, in which the combined movements first appeared when an injury to the cerebellum was added to that of the canals, is of interest.

These experiments on pigeons from which the brain has been removed exhibit the peculiarity that in such cases the derangements of motion persist but for a short period and then cease, to be renewed, however, on striking or shaking the bird. In Experiment No. 5 only, in which the division of the canals was accompanied by a considerable hemorrhage, did the movements continue for a couple of hours after the removal of the cerebrum. On the following day, however, the bird was in the same condition as that of other pigeons from which the brain had been removed. This peculiar phenomenon is most important, and contains the key to the knowledge of the true nature of these derangements of motion. We will therefore consider this point at greater length hereafter.

2. We will now consider the experiments in which the birds were chloroformed.

Experiment No. 6.—A small sponge saturated with

chloroform was held to the beak of a pigeon for a few moments. The bird dropped its head and remained quiet. The loudest noises caused no change of position. The horizontal canal and one vertical canal on the left side were then divided. Some movements of the head from left to right immediately occurred.

The corresponding canals on the right side were then divided, the result being violent movements of the head from right to left, and *vice versâ*, accompanied by falling, and an impossibility to maintain the equilibrium. About half a minute later the pigeon remained quietly standing, the movements of the head having also ceased. On striking or shaking the bird the movements reappeared, to disappear in a few moments. Ten or fifteen minutes later the bird made a voluntary attempt to move from its position, when the characteristic movements immediately reappeared, with even greater intensity than when under the influence of the anæsthetic. The bird finally regained consciousness, and endeavored to escape by flying. The remainder of the experiments completed under chloroform gave precisely similar results: the movements appeared immediately after the operation, disappeared at the end of a few moments, only to reappear when the bird was struck or shaken. So soon as it awakened from the narcosis the characteristic movements began. (In these experiments only minimum doses of chloroform should be used, as the pigeons are easily killed thereby.)

The results of these experiments, on the whole, are entirely in accord with those obtained in pigeons from which the cerebral hemispheres were removed.

In both series of experiments the derangements of motion appear immediately after the operation, and soon subside, to be reproduced only by a change in the position of the bird. The observation made upon pigeons from which the brain was removed, that when the division of the semicircular canals was accompanied by considerable hemorrhage the movements continued for a long time, from half an hour to an hour after the operation, and ceased only at the expiration of this period, is equally applicable to the experiments under anæsthetics. Precisely similar symptoms were observed during sleep in pigeons in which the semicircular canals had been divided; the movements ceased entirely, but recurred so soon as the bird was awakened by a noise.

It is now proper to seek for the interpretation of these two groups of experiments made upon birds deprived of consciousness. There is no difficulty in doing this, if we take into consideration the following points:

1. The derangements of motion resulting from division of the semicircular canals occur even when the birds are in conditions in which they neither perceive pain nor are capable of voluntary movement. It follows necessarily that the derangements of motion are of *reflex origin*, and furthermore, in reference to the explanations above given, that they are a consequence *of irritation of the membranous semicircular canals.*

2. Upon division of the semicircular canals of animals which are unconscious, the resultant movements possess the peculiarity of continuing but a short time after the operation, and, when they have once ceased, of being recalled only by moving or shaking the animal.

This fact proves that in animals operated upon under these circumstances the irritation is not a continuous one, and recurs only on movement.

The manner in which movement causes renewed irritation is readily comprehensible: the most insignificant hemorrhage, the slightest mechanical shock, even mere contact with air of a different temperature, is sufficient to excite intensely an organ so exceedingly sensitive as the membranous semicircular canals. Of the accuracy of this explanation there is evidence in the fact—

3. That even in animals in a state of unconsciousness the derangements of motion continued for a long time in cases wherein the division of the canals was accompanied by severe hemorrhage.

We may now introduce the question as to why it is that these reflex movements are continuous in normal animals, but on the other hand discontinuous in animals which are unconscious.

At the first glance this phenomenon appears to stand at variance with the well-known fact that reflex movements in animals which have been deprived of consciousness are usually more violent than in animals in the normal condition. This contradiction is, however, only an apparent one. We have seen (*sub* 2) that the discontinuance of the movements following division of the semicircular canals is merely a result of the discontinuance of the irritation, which is always reproduced by a movement of the animal.

Birds with the cerebrum intact, however, make continual attempts at flight, and it is these movements which keep up a continuous irritation.

In animals deprived of the function of the cerebrum, the intensity of the derangements of motion is only *apparently* less than in animals under comparatively normal conditions, and this appearance rests simply on the fact that in the first case the irritation which calls for the reflex movements persists but for a short time. If the irritation is present, the derangements of motion in the latter case, if not more violent, are at least as violent as in pigeons in which the brain is intact.

It is also not impossible that the flying movements which the bird, whose cerebrum is uninjured, makes after the division of the semicircular canals, are partially due to the pain resulting from the operation ; and yet, even if this were possible, it would not in the least follow that Flourens was correct in attributing to pain alone the derangements of motion following division of the semicircular canals. The difference between the results of my experiments and the conclusions drawn by Flourens is very great. According to my experiments these movements are of a purely reflective nature, and occur without the presence of consciousness. When consciousness or the appreciation of pain co-operate in the production of these movements, it is only indirectly by exciting the bird to voluntary attempts at flight, and thus affording a cause for the origin of the reflective irritation. According to Flourens, on the contrary, the appreciation of pain is the direct origin of the derangements of motion, and according to his view the bird makes the characteristic movements of the head for the purpose of removing the cause of the pain. But one objection, so far as I am aware, can be raised to the

conclusion deduced from my experiments, and that is as follows: "If each movement of the animal operated upon," it might be said, "causes irritation of the membranous canals, the derangements of motion in pigeons from which the brain has been removed should also be continuous, because, if the bird has once made the abnormal movements in consequence of irritation of the canals, these as well as every other movement must induce further irritation, which would call forth a repetition of the derangements of motion, these producing further irritation of the semicircular canals, etc." The force of this apparently important objection is, however, diminished by the following consideration. The violent convulsive movements made by the bird induce exhaustion both of the motor nerves and of the muscles, and also of the sensitive portions of the membranous canals. Rightly considered, these movements do not continue undiminished in animals with normal brains. In these cases pauses of some minutes occur, during which the animals are quiet as the result of exhaustion. The difference between normal pigeons and those from which the brain has been removed is merely this, that the former, so soon as they have rested, commence making voluntary movements which induce irritation of the membranous canals, while the latter, when once brought to a condition of quiet by exhaustion, remain in that condition until some external impulse again sets them in motion. In a word, exhaustion breaks the chain of phenomena which was implied in the objection just urged.

My experiments having convinced me that the de-

rangements of motion following division of the semicircular canals of the labyrinth were of reflex character, the next point was to determine the *place of transmission of this reflex*. Before directing my experiments to the spinal cord, it was necessary to examine as to whether the transmission might not take place in some portion of the brain which had been left intact in former experiments, namely, in that portion designated as the thalamus.

Experiment No. 7. *Aug.* 5, 1869.—The cerebral hemispheres were entirely removed from a pigeon of medium size. On subsequent division of some of the canals on the right side, the bird made a few movements of the head. The canals of the left side were then divided, followed by violent movements of the head and rotatory movements of the body (the head being carried towards the left). I then removed the cerebellum; the movements continued for a short time in diminished intensity, and finally manifested themselves only by slight movements of the head. Upon placing the pigeon on the ground the rotatory movements recommenced in the same direction as before; the head was pressed with the occiput against the ground. Upon removal of the thalami optici, the head rested quietly upon the ground, and the bird died.

Experiment No. 8. *Aug.* 5, 1869.—The cerebellum was mutilated in a pigeon. Rotatory movements backwards and towards the left followed. The canals on the right side were then divided, when there occurred violent movements of the head and the body of a complicated character. These were not "mouvements de

manège," but a reeling from right to left. The canals on the left side were then divided. The movements remained the same in character, but the excursions were greater. The pigeon dashed the head forcibly towards the right (previously towards the left). The cerebral hemispheres were then removed. The movements continued. I then removed the remainder of the cerebral substance and the thalami. The movements ceased and the bird remained alive.

Experiment No. 9. *Aug.* 12, 1869.—I removed the right cerebral hemisphere and the right thalamus from a pigeon. Immediately thereafter the bird twisted the head downwards, so that the beak was directed upwards. In so doing the head was twisted from left to right. The bird then turned violent somersets backwards, at the same time falling towards the right side. Shortly after the movements of the head ceased. I then divided the external vertical canal on the right side. The pigeon immediately shook the head from right to left; the body was supported upon the tail and rotated from left to right. The pigeon fell towards the right. I then removed the left cerebral hemisphere and the left thalamus: the movements immediately ceased entirely. Division of the left external vertical canals did not cause them to recur.

These experiments show that removal of the thalamus is followed by immediate cessation of the movements even in those cases in which the birds survived the operation for some time. (See Experiment No. 8.)

The ninth experiment shows, furthermore, that the removal of one hemisphere and one thalamus presents

no hindrance to the occurrence of the symptoms, but that the latter cease only so soon as the thalamus of the remaining side is removed. We cannot, of course, attach any importance to the movements which occurred after simple removal of one hemisphere and one thalamus. In these experiments the circumstance that, following division of one of the right vertical canals (therefore only unilateral injury to the semicircular canals), violent and continued movements occurred, and further that these were, not as is usual from the wounded to the normal side, but in a contrary direction, is particularly remarkable and difficult of explanation.

It is proved, therefore, by the above experiments, that the transmission of the irritation from the sensitive portions of the semicircular canals to the motor nerves which take part in the production of the derangements of motion, occurs in the thalamus. This result naturally obviated the necessity of proceeding to experimental division of the spinal cord. The results of experiment No. 9 are difficult of explanation. Is it possible that a portion of the nerve-fibres coming from the canals intersect in the thalamus?

Condensing the results of my experiments on pigeons, I believe that I have proved the following points:

1. That the derangements of motion following division of the semicircular canals are the result of this injury, and not of an accompanying injury to portions of the brain.

2. That the vomiting observed by Professor Czermak

in his experiments was the result of an accompanying injury of the cerebellum.

3. That the derangements of motion are the result of irritation of the membranous canals, and not of paralysis.

4. That the irritation of the semicircular canals produces the convulsive movements *reflectively*, without participation of consciousness. Consciousness participates in these effects only in so far as it gives rise to renewed irritation, by inciting the animal to voluntary movement.

5. The communication of this reflex excitation from the nerves of the membranous semicircular canals to the motor nerves takes place in the thalamus.

Appendix.—Experiments on Rabbits.

According to a well-known observation of Dr. Brown-Séquard, division of the nervus acusticus induces the same derangements of motion as lesion of the semicircular canals. In this connection I have instituted a series of experiments on rabbits, which I will briefly describe, and of which the following experiment serves as an example:

Experiment No. 10.—The nervus acusticus in a rabbit was divided from the tympanum. (See the method described by Claude Bernard for division of the facialis, in his *Leçons sur la Physiologie et la Pathologie du Système nerveux*. Tome ii., 18 et 19.) For this pur-

pose the knife was carried into the tympanum forwards and upwards. There immediately followed the characteristic movements of the head from right to left, and, in addition, the "mouvements de manège." The right ear seemed to have lost its hearing power. The "mouvements de manège" continued for several days, but diminished in intensity during sleep. If the animal was shaken or struck, they increased in violence. On the third day the animal was killed. The dissection showed that while the right auditory nerve was almost completely divided, at the same time the semicircular canals of this side were partly crushed and partly broken in. Other experiments gave precisely the same result. In all cases the canals shared in the injury. A division of the nervus acusticus, therefore, without accompanying injury to the semicircular canals, cannot be accomplished (at least by this method).

In these experiments the constant occurrence of the "mouvements de manège" without injury (as was shown on dissection) to any portion of the brain was remarkable, and furthermore, the occurrence of continuous derangements of motion accompanying only unilateral injury of the canals. Vomiting was not observed in any of these experiments.

Remark.—The preceding paper, written in French, was sent, competing for a prize, to the *Académie des Sciences, in Paris*, on June 6th, 1870. External circumstances prevented the author from publishing it earlier, and from availing himself of later researches, especially those of Prof. GOLZ. The preceding investigations, starting from new points of view, yielded results which are, perhaps, not unworthy of the notice of the profession.

THE AUTHOR.